Manfred Mühlbacher, DB 9 SB

A 2.3 GHz Prescaler (: 100)

New, inexpensive integrated preamplifier and divider circuits allow direct frequency measurements to be made up to and in excess of the 13 cm band, and led to the design of the prescaler described in this article. The designation "inexpensive" does not necessarily mean that they are cheap: The required ICs are most certainly worth their price, but are not cheap for us radio amateurs! The subsequent frequency counter needs only to have a cutoff frequency of 25 MHz, and should have a good time base!

1. PRESCALER CONCEPT

The block diagram of the prescaler is shown in **Figure 1**. It is provided with a PIN diode attenuator at the input, and two preamplifiers. This is followed by the fast 2:1 divider. Half the input frequency is usually too weak in order to drive the 10:1 divider SP 8668 B (Plessey), and for this reason, a 20 dB intermediate amplifier is provided. A subsequent 5:1 divider then brings the overall frequency division ratio to 100:1. The input frequency divided by 100 is now available at ECL-II level. If TTL-level is required, this can be achieved by providing a converter stage using an AF or switching transistor and a Schottky gate. This will generate steep impulses at TTL-level, that can be processed in any subsequent frequency counter having a band width of at least 25 MHz. An offset voltage as described in (1) is not to be expected.

The components within the dashed lines: the electronic attenuator, and the first preamplifier, can be deleted or provided later. **Figure 2** shows the prescaler equipped in this manner.

1.1. Electronic Attenuator

In order to increase the dynamic range of the prescaler, it was provided with a voltage-controlled PIN diode attenuator type UTF-025 manufac-

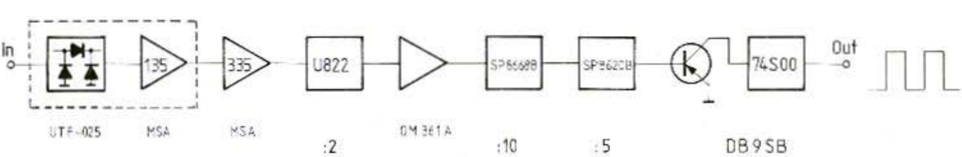

Fig. 1: Block diagram of the 2.3 GHz divide-by-100 prescaler

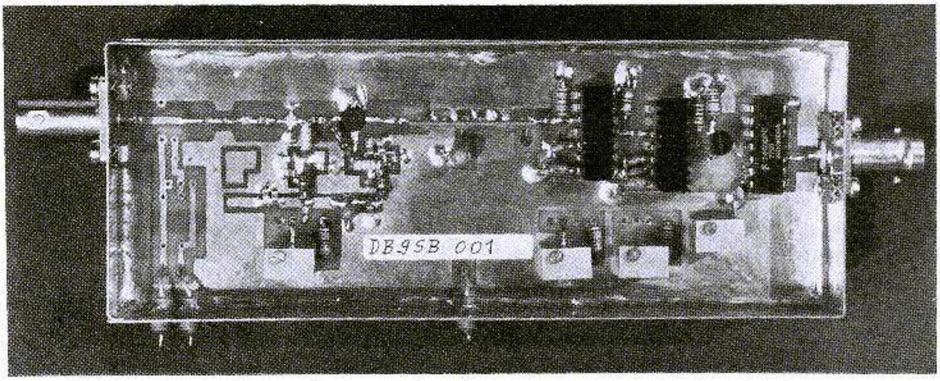

Fig. 2: In this prototype, the author has deleted the PIN diode attenuator and the first preamplifier

tured by Avantek. It operates in the frequency range of 5 to 2500 MHz. Its input and output impedance is 50 Ω. The maximum attenuation amounts to 40 dB at 10 MHz, approx. 25 dB at 1 GHz, and 20 dB from approximately 2 GHz up. The maximum permissible input power amounts to +23 dBm, which corresponds to 200 mW or 3.1 V into 50 Ω. At a price of approximately 100 US-Dollar (Summer 1984), this PIN attenuator is only a quarter of the price of a mechanical attenuator. The connections of this component are shown in **Figure 3**. Since the prescaler is very sensitive, attention should be paid that the input power at 2300 MHz should never be more than 1 to 2 mW, corresponding to 0.223 V into 50 Ω. May be one of our readers has a useful recommendation how this attenuator can be automatically controlled by the input signal.

1.2. Preamplifier

At present, two main types of internally matched amplifiers are suitable for use with an operating voltage of 5 V: The GaAs-FET types CGY manufactured by Siemens, and the monolithic silicon amplifier (MSA)-types manufactured by Avantek. The latter provide a far better value for money, and are therefore used in the following description. Construction is not critical if the information given in the description is observed. The number of amplifiers that were destroyed during the development could be limited to four.

The case and the basic circuit of the Avantek-MSA amplifiers are shown in **Figure 4**. The other types given in **Table 1** mainly differ from each other in their higher output levels.

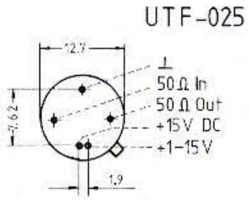

Fig. 3: The electronic attenuator UTF-025

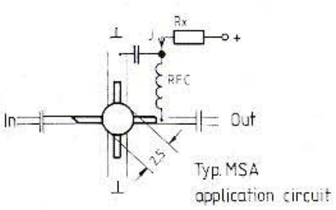

Fig. 4: Monolithic microwave amplifier manufactured by Avantek

Table 1

Type	U_B	Gain (2.4 GHz)	P_{out} (25 °C)	Current *	Usable to GHz/Gain
MSA 0135/21	5.2 V	12.00 dB	1.8 dBm	17 mA	4 GHz / 7.2 dB
MSA 0235/21	5.2 V	10.40 dB	3.5 dBm	25 mA	4 GHz / 6 dB
MSA 0335/21	5.2 V	10.70 dB	11.0 dBm	35 mA	4 GHz / 6.8 dB
MSA 0420/21	6.5 V	7.53 dB	17.8 dBm	90 mA	4 GHz / 4 dB
MSA 0435/21	5.5 V	7.30 dB	13.2 dBm	50 mA	4 GHz / 4 dB
MSA 0470/21	5.5 V	7.56 dB	13.2 dBm	50 mA	4 GHz / 4 dB

*Since these are "Shunt-feedback" amplifiers, it is necessary to observe the given currents for maximum gain. The voltage should also be set as exactly as possible. In this manner, a series circuit comprising the MSA 0135 and MSA 0335 will provide a gain of approximately 30 dB up to 1 GHz, which drops continuously to 20 dB up to 2.6 GHz. If no care is made with the currents, this can cause a loss of gain of up to 10 dB in the cascade circuit.

Avantek has mentioned that the MSA types will be available in a cheaper case in the near future with prices in the order of 10 US-$.

1.3. Frequency Dividers

A frequency divider type U 822 manufactured by Telefunken is used as 2.3 GHz-divider. It divides the input frequency by 2. This IC is selected at 2.3 GHz in the factory. It was mainly developed for use for the first IF of future satellite TV-receivers. Later, due to the high quantities involved, the price should finally drop to approximately 20 US-$. **Figure 5** shows the case and connections of this integrated divider type U 822 BS.

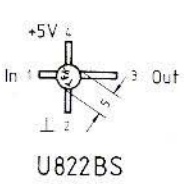

Fig. 5: The divide-by-two prescaler up to 2.3 GHz manufactured by Telefunken

The divide-by-two module U 822 is followed by a divide-by-ten IC manufactured by Plessey, which is designated SP 8668 B, that operates up to 1.5 GHz. It requires an input voltage of approximately 400 mV (peak-to-peak) to operate reliably. Since the output voltage of the U 822 at an input frequency of 2320 MHz only amounts to approximately 70 mV (peak-to-peak), it is necessary for an intermediate amplifier to be provided using the inexpensive OM 361 A. Telefunken has stated that a new divider with a higher output voltage will be produced at a later date. In this case, it will be possible for the intermediate amplifier to be deleted.

The subsequent divide-by-five IC type SP 8620 B manufactured by Plessey increases the overall division ratio to 100.

Further notes regarding the use of other frequency dividers with differing division ratios are to be mentioned in Section 7.

2. OVERALL CIRCUIT DIAGRAM

The complete circuit diagram of the 2.3 GHz prescaler module is given in **Figure 6**. The amplifier and frequency dividers will only operate reliably when the given voltages and currents are maintained. For this reason, all voltages should be individually stabilized electronically and be exactly adjustable with the aid of multi-turn trimmer potentiometers. It is possible for the voltages to be slightly increased during the alignment process in order to find the most favorable value.

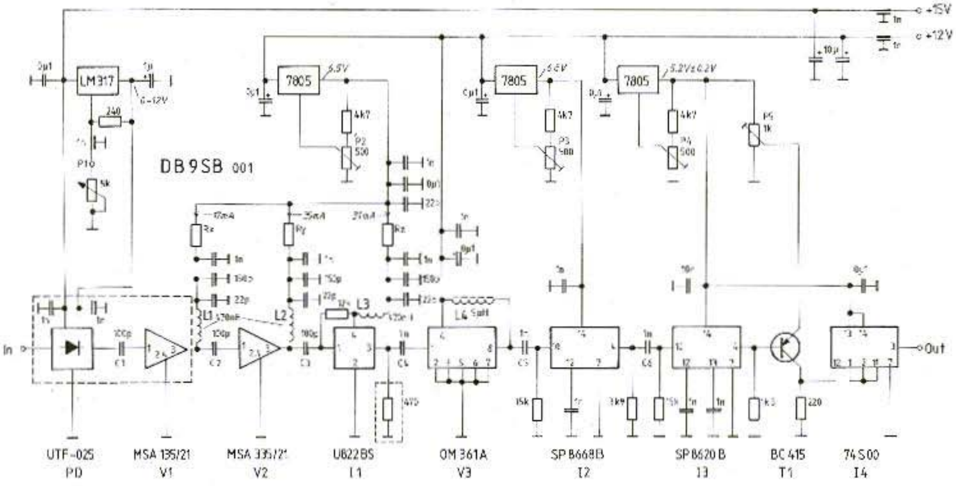

Fig. 6:One will notice several chokes and extensive bypass of the microwave dividers and amplifiers in the overall circuit diagram of the 2.3 GHz prescaler

Unfortunately, the PIN diode attenuator requires an operating voltage of 15 V. The variable DC-voltage for adjusting the attenuation (P 1, LM 317) is derived from this voltage. **Figure 7** shows the connections of this voltage stabilizer.

The 470 Ω resistor within the dashed lines at the output of the divide-by-two IC I1 originates from a suggestion by HB9MIN: The resistor increases the output voltage of the U 822 by approximately 8 dB. Since this is still not sufficient for driving the SP 8668, it is possible for this resistor to be deleted.

2.1. Special Components

PD:	UTF-025 (Avantek)
V 1:	MSA 0135/21 (Avantek)
V 2:	MSA 0335/21 (Avantek)
V 3:	OM 361 A (Philips)
I 1:	U 822 BS (Telefunken Electronic)
I 2:	SP 8668 B (Plessey)
I 3:	SP 8620 (Plessey)
I 4:	74 S 00
T 1:	BC 415, BC 560 or similar PNP transistor
L 1 – L 3:	0.47 μH miniature choke
L 4:	4.7 μH miniature choke
C 1 – C 3:	100 pF miniature chip capacitor (ATC or similar)
C 4 – C 6:	1 nF miniature chip capacitor (ATC or similar)

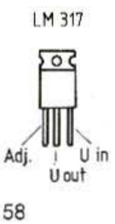

Fig. 7: Voltage stabilizer LM 317 for the UTF-025

Other bypass capacitors:

Ceramic disk, or miniature chip capacitors;
3 ceramic feedthrough capacitors 1 – 2 nF, for solder mounting;
Polarized capacitors: Tantalum electrolytics (bead type);
4 trimmer potentiometers, for vertical mounting, 10 x 5, spacing 5 x 2.5 mm;
2 heat sinks for DIL 14;
1 metal case 148 x 56 x 30 mm;
3 voltage stabilizers 7805;
1 voltage stabilizer LM 317.

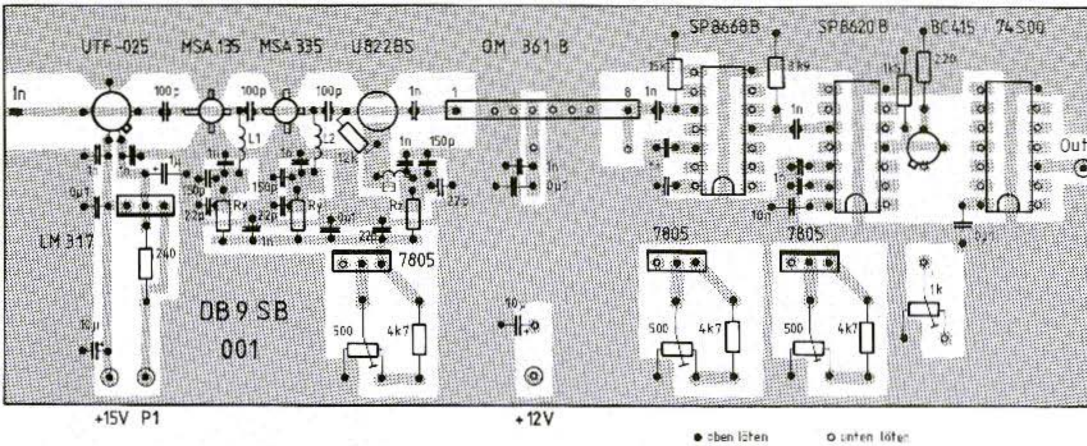

Fig. 8: Component locations on the double-coated PC-board DB9SB 001; the other side of the board is also provided with conductor lanes

3. CONSTRUCTION

The circuit diagram given in Figure 6 can be accommodated on PC-board DB9SB 001, which is shown in **Figure 8**. This board is double-coated, but without through-contacts. The material used is epoxy glassfibre with a thickness of 0.8 mm. The first prototypes were made on RT/duroid with a thickness of 0.79 mm, however, the epoxy material did not cause practically any deterioration of the sensitivity after changing the conductor lane width to 1.37 mm for 50 Ω. The price difference when using a board of 146 x 54 mm is considerable!

A coaxial connector suitable for SHF must be used at the input of the divider, preferably using a flange type. The PC-board is soldered around the edges on both sides so that the same spacing is provided above and below the board. The four voltage stabilizers, their bypass capacitors, and

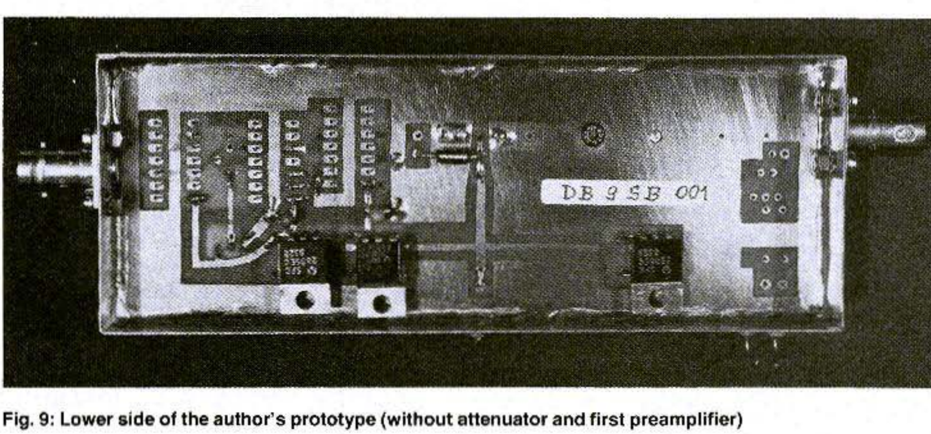

Fig. 9: Lower side of the author's prototype (without attenuator and first preamplifier)

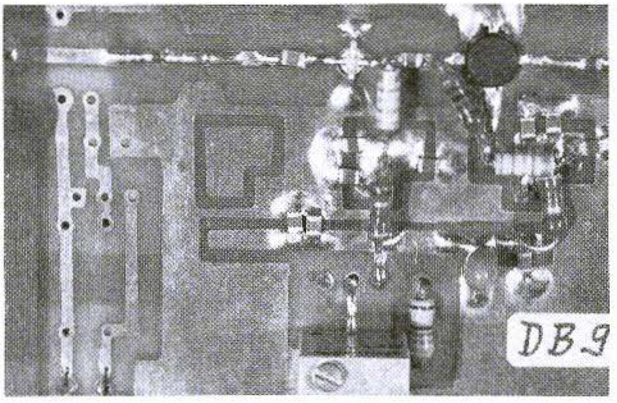

Fig. 10:
Close-up of the input circuit

choke L 4 are soldered into place on the lower side of the board, which is the side marked with the author's call sign. The voltage stabilizers are then bent back as shown in **Figure 9**.

The conductor lane cutouts for PD and C 1 can be cut with the aid of a sharp knife – approximately 6 mm is required for the attenuator and 1 mm for the chip capacitor. The 50 Ω line is provided as a continuous line, in order to allow the prescaler to be used without PIN diode attenuator and preamplifier.

The miniature chip capacitors can be mounted easily if one's eyes are good, or when a magnifying glass is used. The wire ends of the bypass capacitors must, however, be as short as possible, especially those used in conjunction with the Plessey ICs. Suitable holes are drilled in the PC-board for the Avantek preamplifiers and the Telefunken divide-by-two prescaler. These components are placed onto the board with the markings facing downwards into the PC-board. This can be seen in more detail in **Figure 10**.

4. ALIGNMENT

The PC-board can be completely equipped with the exception of capacitors C 4 and C 5. All trimmer potentiometers should be adjusted to their fully anticlockwise position.

The voltages and currents given in **Table 2** should be adjusted after connecting the operating voltage(s).

Potentiometer	Act. comp.	Current	Voltage (V)
P 4	I 3 und I 4	–	5,2 ± 0,2
P 3	I 2	–	6,8 ± 0,3
P 2	V 1, V 2, I 1	–	6,5
R_x	V 1	17	–
R_y	V 2	35	–
R_z	I 1	31	ca. 5

Table 2

The author used metal-film types for the dropper resistors.

This is followed by connecting the output of the prescaler via a short coaxial cable to an oscilloscope with a bandwidth of at least 25 MHz. Firstly examine I 3 for any tendency to self-oscillation. This is done by rotating P 5 in a clockwise direction until approximately 5 V (TTL-high) is present at the output, switching the oscilloscope to AC-voltage coupling, and to a sensitivity of 100 mV/div. If P 5 is rotated further, and if sinewave oscillations are noticed, this will indicate that I 3 is oscillating and it will be necessary to connect 15 kΩ between pin 10 of I 3 and ground (below!).

After soldering C 5 into position, one will immediately notice whether I 2 breaks into oscillation. Until now, every SP 8668 B used by the author has broken into oscillation! 15 kΩ at the input is all that is required for neutralization.

The preamplifier OM 361 A will not break into oscillation – in contrast to its predecessor, the OM 361. I 1, on the other hand, will oscillate at the frequency of its highest sensitivity, which is at approximately 1.4 GHz. It is necessary here to provide a resistor of approximately 12 kΩ between input and +5 V, that is between pins 1 and 4 of the U 822 BS.

No tendency to self-oscillation was noticed in the case of the preamplifiers. The oscilloscope image should now be free of amplitude variations when rotating P 5 slowly through its range.

If an oscillator with an output power of 1 mW in a frequency range of between 1000 and 1500 MHz is fed to the prescaler, a virtually square-wave TTL signal will appear on the oscilloscope on rotating P 5. The prescaler is now connected to a counter, and P 5 adjusted so that the counter provides a stable reading. This completes the alignment.

The given frequency range was selected since the dynamic range of the module is greatest in this range, as can be seen in **Figure 11**. The dynamic range is considerably less in the 13 cm band at 2320 MHz, which means that it is necessary to

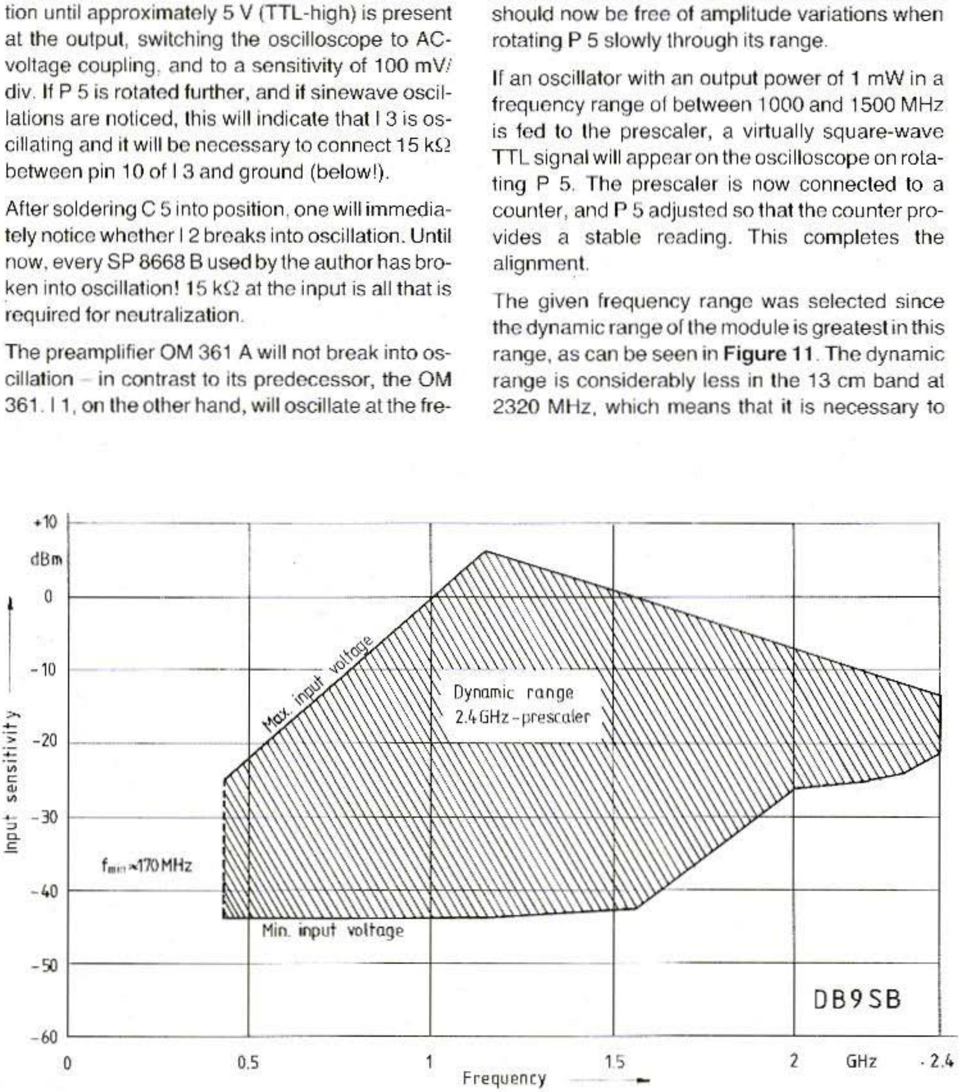

Fig. 11: The input signal to be measured must be within the shaded area

use a preamplifier and to adjust the PIN diode attenuator in order to obtain a stable reading.

The operating current of the complete prescaler module is in the order of approximately 320 mA.

5. NOTES

It has been found that I 1 works best when the power at the input of the first divider is between 0 and +5 dBm. If the module is used without PIN diode attenuator, it is necessary to ensure with the aid of suitable attenuators (fixed or variable) that the input power is not too high. If it is in excess of the dynamic range (see Figure 11), a reading of 000 will be indicated.

The highest operating frequency measured on the author's prototype was 2430 MHz without cooling, and approximately 2.6 GHz when I 1 was cooled. The lower frequency limit is in the order of 140 to 170 MHz. The author would like to point out, however, that his U 822 was selected in a Telefunken laboratory at 2400 MHz. Those available on the market are, on the other hand, automatically measured at 2300 MHz.

For the first time, it is now possible for radio amateurs to measure frequencies up to 2.3 GHz. At present, there are no commercially available counters on the market that can measure this very high frequency directly! Of course, this high technology has its price: When fully equipped, the components used in the prescaler module alone will have a value of approximately 900.– DM. Even without PIN diode attenuator and first preamplifier, it will still be approximately 500.– DM. However, the high value is relative when one considers that a commercial prescaler of this type would most certainly cost many times this price. In addition to this, suitable measuring equipment is becoming more and more important, the higher one goes in the microwave range.

The author hopes that he has been able to bridge a gap, and will be only too pleased to assist interested readers in obtaining some of the components. At present, the author is working on a new frequency counter which should be able to count up to 2.5 GHz. It will have 9 digits and the frequency should be indicated after a measuring period of 0.4 s. A special feature is a switchable time base, which allows one to use prescalers with a non-decadic division ratio in the future. If this frequency counter is of interest to our readers, the author will be only too pleased to write an article on it.

6. REFERENCES

1) M. Mühlbacher: 1.6 GHz durch 100 Teiler cq-DL 7/1983, page 319 – 322
2) Telefunken-Electronic, Heilbronn: Datenblätter U822BS, U824BS
3) Avantek: Cascadable Monolithic Silicon Integrated Amplifier
4) Plessey: High-Speed Dividers Handbook, SP8000 Series
5) E. Zimmermann, HB9MIN: 2.5 GHz-Teiler Tagungsheft der VHF/UHF 1984 München
6) Das TTL-Kochbuch, Texas Instruments
7) H. Mazur, DL6WA: Einfacher Vorteiler für Frequenzen bis über 1 GHz mit Dezimalisierung des Teilfaktors cq-DL 2/1983, page 62 – 63

7. POSSIBLE MODIFICATIONS

At present, three different prescalers are known to the author for frequencies over 2 GHz:

U 822 BS	2.3 GHz	÷ 2	Telefunken
U 824 BS	2.3 GHz	÷ 4	Telefunken
SP 8712	2.5 GHz	÷ 4	Plessey

If one wishes, it is possible to use the following dividers subsequently: U 624 (÷64), or U 626 BS (÷256). The advantage is that both possess a built-in preamplifier. The disadvantage is the non-decadic division ratio which must be further divided according to (7) in order to achieve a total frequency division of 1000.

If one knows the internal circuitry of one's counter well enough, it is possible for the time base to also be modified. This, on the other hand, also has its effects on the other prescalers already built in. The most elegant way would therefore be to provide an additional board behind

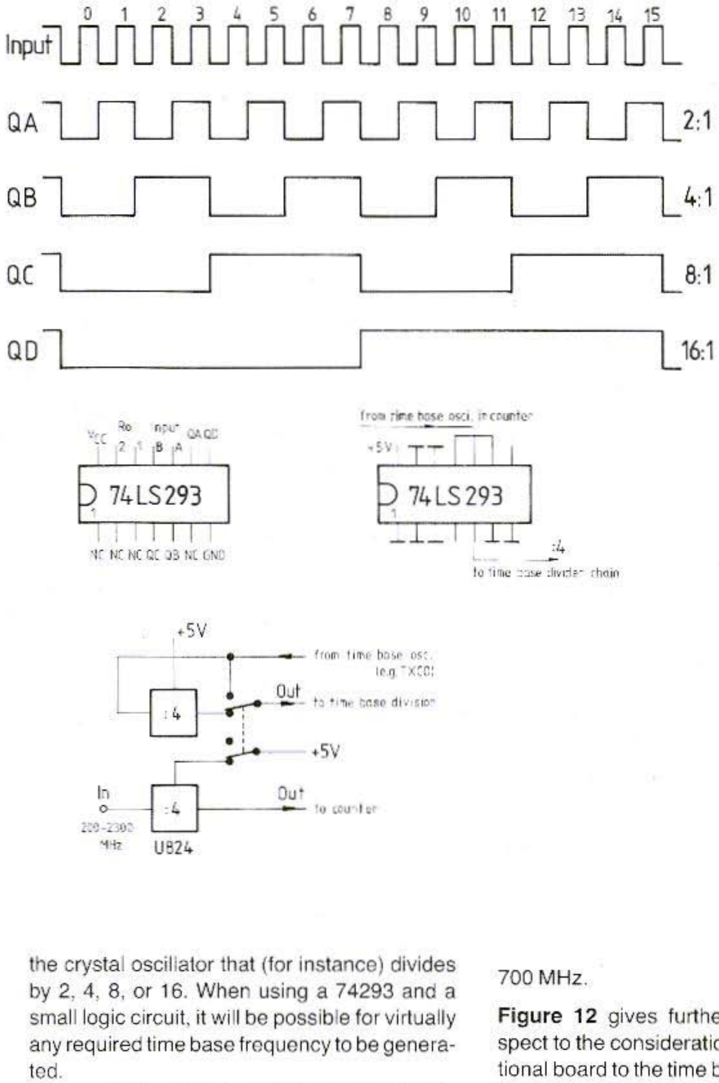

Fig. 12: Recommendation for a switchable divider by 2, 4, 8, and 16 together with its pulse diagram

the crystal oscillator that (for instance) divides by 2, 4, 8, or 16. When using a 74293 and a small logic circuit, it will be possible for virtually any required time base frequency to be generated.

When switching on a prescaler, one could automatically switch the time base to the required frequency. In this manner, it would be possible to use the new SP 8712 manufactured by Plessey, which is a 2.5 GHz divide-by-four prescaler. One only requires a subsequent division ratio of 10 and to divide the time base frequency by 4. The most simple way would be to divide by 5 after the SP 8712, however, no divide-by-five prescalers are known that operate up to 700 MHz.

Figure 12 gives further information with respect to the consideration of providing an additional board to the time base. The 74293 is a binary, four-bit counter. In order to have it count up to 16, it is necessary for input B (pin 11) to be connected to output QA (9). The divided oscillator frequencies are then taken as required from outputs QA – QD (pulse diagram). The inputs Ro (1) and Ro (2) are connected to low. If one is operating without prescaler, the oscillator frequency is fed directly to the time-base divider chain via a relay contact. Figure 12 shows a division-by-four as an example.